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Original Article

PROCESSING AND MECHANICAL TESTINGS OF 7075 AL MATRIX COMPOSITE REINFORCED WITH AL2O3 NANO-PARTICLES FABRICATED BY STIR CASTING ROUTE

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ABSTRACT

There is a massive demand for lightweight, cost-effective and rapidly processed products because of their significant level of excellence in these days. In the present work, the impact of electric stir casting on 7075 based aluminum alloy developed along with Nano Al_2O_3 with particle dimension (20-30) Nano microns and weight percentages 1.0, 2.0,3.0, 4.0 has been studied. Many researchers revealed the non uniform distribution of Nano particles possessing high porosity in the matrix. Electric stir casting can prevent the troubles integrating with mechanical stir casting. By infusing Al_2O_3 particulates right into Aluminium alloy, the Aluminium 7075/1 % Wt. Al_2O_3 is giving place to Nanocomposite. By incorporating 1% Micro magnesium powder improved the wettability of the reinforcement. SEM micrographs reported that the Nano particles were consistently dispersed throughout the matrix and also executed the efficient grain microstructure. The tensile strength, hardness, and impact results of Al7075/1 % Wt. Al_2O_3Nanocomposites have efficiently increased as compared to the Al7075 base alloy.

KEYWORDS: Al 7075, Al_2O_3, Magnesium, SEM & EDX

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INTRODUCTION

In the recent days, lightweight aluminum alloys favored engineering material for aerospace, automotive and marine industries, because of their remarkable physical and Thermal Properties. Among the various series of aluminum alloys, the Al7075 alloy is highly corrosion resistant and qualitative one and also shows good strength and finds a lot of applications in the areas of automobile, construction and space applications. The metal matrix composites developed from aluminum alloys are of broad concern, because of their high strength, fracture strength, stiffness and wear resistance. Besides these MMCs' are of exceptional when reinforced with Ceramic particles [1]. Making usage of Al 7075 MMCs' has been limited in specific applications such as aerospace as well as armed force weapons, because of high handling expenditure. In the current days, Al alloy matrix composites have been made use for the manufacturing of automobile parts such as disc brake, engine piston, cylinder liner and so on [2]. There is a categorization of the production methods for Al MMCs' into three types such as (a) solid-state process (b) Liquid state process and Powder metallurgy [3, 4]. By the method of the liquid state, the process strengthened

the particle of Al MMCs' and refined more. Electric stir casting is an appealing handling technique, because it is fairly less cost and also make use of it for a wide selection of materials and conditions to handle. The Rate of interest in MMCs for usage in the aerospace, auto sectors as well as various other architectural applications has grown up over the previous 30 years. The outcome of the accessibility of sensibly low-priced reinforcements and also the growth of the different processing techniques which lead to reproducible microstructure as well as Properties [5,6]. Ceramic Nanoparticles reinforce the toughness of aluminum by this there is a considerable enhancement in the toughness of lightweight aluminum. Currently, there are several manufacturing techniques of MMCs' consisting of in -situ method [7,9]. The instance of escalation in particle reinforced metal matrix MMCs has been researched long-ago; however, the required permission is not there for its beginning. Developing dislocation models for diffusion of toughened alloys are specially designed to account for strengthening materials [10, 11]. MMCs reinforced with Nano-ceramic particles, whiskers have gotten raising interest, because of their possibly higher fracture toughness and strength [12,15]. particulate reinforced aluminum metal matrix composites find prospective applications, particularly in automobile engine components such as cylinders, brake rotators, piston and in space applications[15].

The primary purpose of this work is to prepare the MMCs of Al 7075 reinforced with Al_2O_3 Nano ceramic powder with a dimension size (20-30nm) and study of its mechanical behavior.

SELECTION OF MATERIALS

While choosing a material, one should be very cautious and take the most exceptional care, so that it suits the defined application. That integrates an assortment of the matrix as well as reinforcement materials.

Matrix Material

There is a selection of Aluminium 7075 alloy as matrix material because of their excellent strength-to-volume ratio, unique mechanical properties, high thermal conductivity, cost-effective and ethical tribological properties. It contains zinc, magnesium, and copper as its major alloying elements as shown in Table 1

Table 1: Chemical Composition of Aluminium Al7075

Element	Fe	Si	Mn	Cr	Cu	Ti	Zn	Mg	Others	Al
% of weight	0.198	0.052	0.055	0.195	1.458	0.047	5.989	2.151	0.025	Remainder

The main aim of alloying 7075 Al alloy is to improve strength, corrosion resistance, machine ability and also weld ability. Mechanical Properties of 7075 Al-alloy tabulated in Table 2.

Table 2: Mechanical Properties of Aluminium Al7075

Density (gm./cm^3)	Poisson Ratio	Hardness (BHN)	Tensile Strength(MPa)
2.7	0.33	60	220

Reinforcement Material

There is the use of alumina which is nothing but Aluminium oxide (Al_2O_3) Nanoparticles as the reinforcement material with an average particle size of (20-30 nm). Extreme hardness, high wear resistance, and low density are the characteristics of typical aluminum oxide particles. The Table 3 shows the tabulation of the mechanical properties of aluminum oxide.

Table 3: Properties of Aluminium Oxide

Density (gm/cm^3)	Poisson Ratio	Hardness (BHN)	Elastic Modulus (MPa)
3.86	0.22	1500	375

EXPERIMENTAL PROCEDURE

The fabrication of the metal matrix composites by using the stir casting method, shown in Figure. 1(a), which is best and cost-effective from all the readily available techniques for producing metal matrix composites in large amounts. In this method, the raw material of Al7075 which is in the shape of the rectangular bar is melted in an electric furnace in a graphite crucible and heated up to 900°C. After that, the integrated aluminum oxide (Al_2O_3) which is wholly blended with 1% of magnesium to improve the wettability is pre-heated at 650°C and poured into the molten matrix. Next, the mixture is stirred with a stainless steel stirrer, maintaining uniform speed as shown in Figure. 1(b), for the equal diffusion of reinforcement material inside the metal matrix. Lastly, there is a release of the solidified composites with the aid of air to minimize the settling time of particles. There is a cutting of solidified composite of corresponding dimensions and shapes as per ASTM standards for conduction of tests [10].

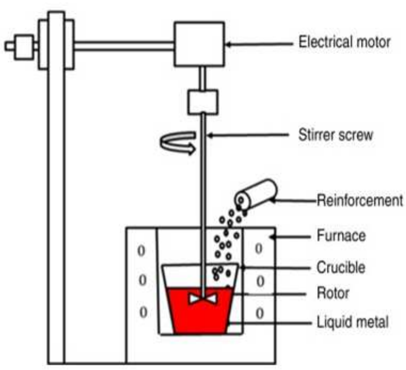


Figure 1 (a): Stir Casting

Figure 1 (b): Electrical Stirrer

Table 4: Composition of the Test Specimens

Specimens	Weight of Al7075 (in gm)	Weight of Al7075 (in %)	Weight of Al_2O_3 (in gm)	Weight of Al_2O_3 (in %)	Weight of Mg (in gm)	Weight of Mg (in %)
A	1000	100	0	0	0	0
B	608	99	6.08	1	6.08	1
C	580	98	11.8	2	5.8	1
D	572	97	18	3	5.8	1
E	583	96	24.7	4	5.9	1

RESULTS AND DISCUSSIONS

The Al7075 alloy/Al_2O_3 Metal matrix Nanocomposite obtained by stir casting process and the following tests like hardness test, tensile test, and toughness test are done to provide the mechanical properties. There is a tabulation of comparable results and the same are displayed in the graphs.

Density and Porosity Measurement

Density is one of the key properties that reveal, characteristics of composites. There was a determination of the experimental density values of the composites by using Archimedes principle, and the theoretical values are calculated

using the formula shown below. Here we found reported Porosities by a difference between the theoretical density and experimental density. Al 7075alloy density value is 2.7gm/cm^3 and density of Al_2O_3 is 3.7 gm/cm^3.

$$\rho_c = \frac{1}{\left(\frac{W_{Al}}{\rho_{Al}}\right)+\left(\frac{W_{Al_2O_3}}{\rho_{Al_2O_3}}\right)+\left(\frac{W_{Mg}}{\rho_{Mg}}\right)}$$

% Porosity = (Theoretical density-Experimental density) / (Theoretical density) X 100

Table 5: Density and Porosity Measurement Values

Alloy	Theoretical Density Values (gm/cm^3)	Experimental Density Values (gm/cm^3)	% of Porosity
Pure Al7075	2.7	2.7	
1%Al_2O_3 +1%Mg	2.6940	2.6600	1.2620
2%Al_2O_3 +1%Mg	2.7026	2.6666	1.3320
3%Al_2O_3 +1%Mg	2.7116	2.6903	0.7855
4%Al_2O_3 +1%Mg	2.7204	2.6450	2.7716

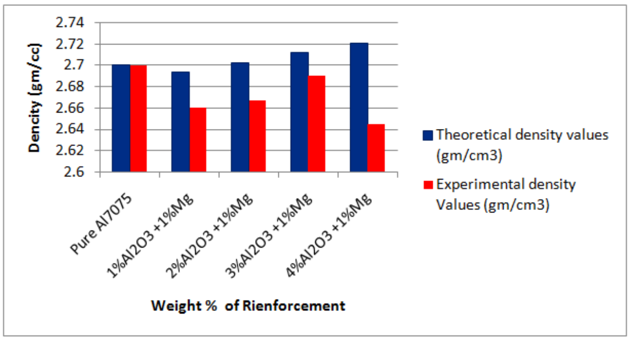
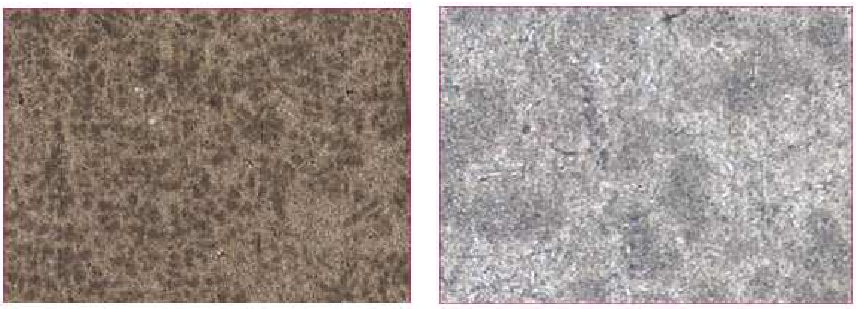


Figure 2: Density and Porosity for Different Compositions

Figure 2 shows the variation of theoretical density and the experimental density concerning the weight percentage of reinforcement. It is clear from the chart that the density decreases with increasing weight % of Nano Al_2O_3 particles.

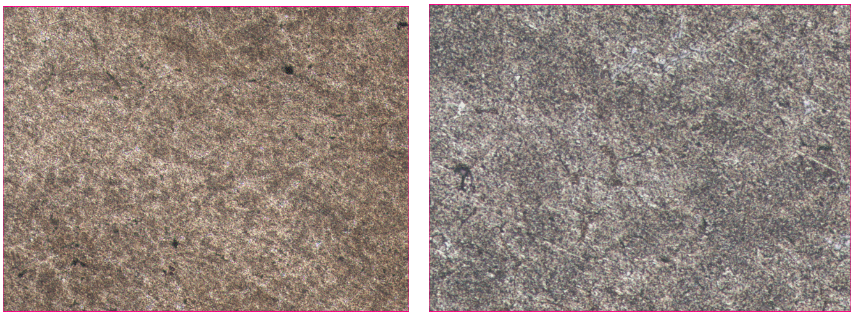
Microstructure Evaluation

There was a cutting of the microstructure of the specimens as per conventional metallographic process, and the surface of samples was grinding through fine mesh size grit papers. After using Keller reagent as an etchant as well as the microstructures of the etched samplings were observed by using an optical microscope.



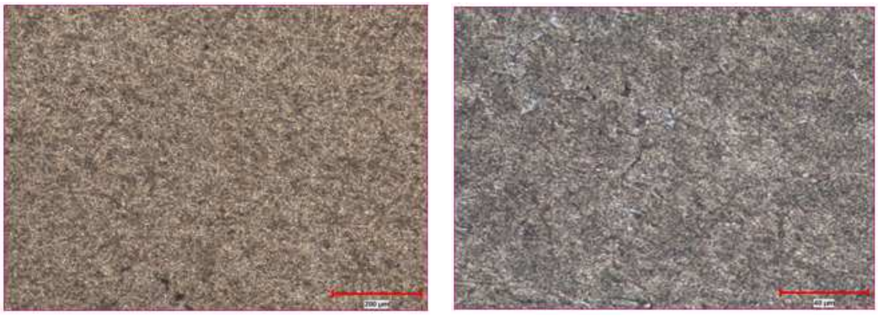
(a) **(b)**

Figure 3: Optical Microscopic Images of Pure Al 7075
(a) 100 X b) 500X



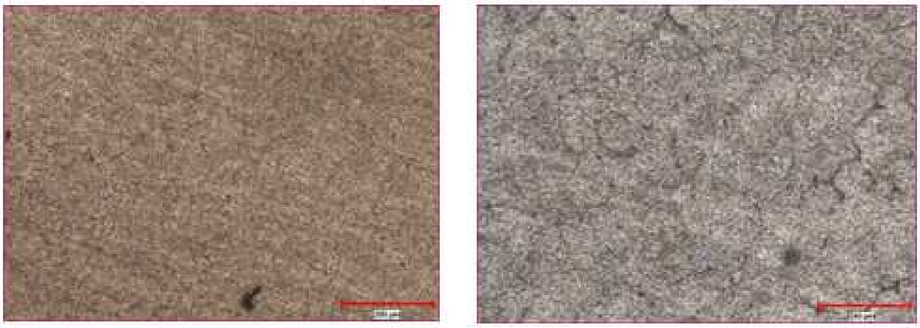
(c) (d)

Figure 3: Optical Microscopic Images of 1% Al2O3 + 1% SiC + 1% Mg (c) 100X (d) 500X



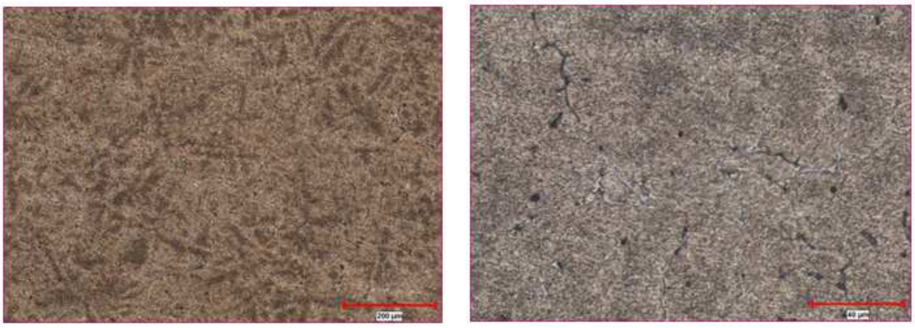
(e) (f)

Figure 3: Optical Microscopic Images of 2% Al_2O_3 + 2% SiC + 1% Mg (e) 100X (f) 500X



(g) (h)

Figure 3: Optical Microscopic Images of 3% Al_2O_3 + 3% SiC + 1% Mg (g) 100X (h) 500X



(i) (j)

Figure 3: Optical Microscopic Images of 4% Al_2O_3 + 4% SiC + 1% Mg (i) 100X (j) 500X

Optical microscope images show the Microstructure of the object. In my research work, four distinct specimens are checked with 100X and 500 X magnifications. Four samples are different in quantity of enhancement of reinforcement. Depending on the weight percentage of added reinforcement particles, crystalline structure has changed. The consistent images are shown in Figure 3. (a), (b), (c), (d), (e), (f), (g), (h), (i), (j).

MECHANICAL TESTING'S

Tensile Strength Test (ASTM E8)

The tensile test was carried out on the computerized universal testing machine of more than 1000 KN load capacity. The Main purpose of this analysis is to determine yield strength, ultimate strength, and the percentage of elongation.

Figure 4: Tensile Test Specimen for different Compositions

There is a tabulation of calculated tensile properties for the sample I to sample V in Table 5, and there is an increase in the value of specimen III.

Table 5: Tensile Strength

Alloy (Al 7075)	Yield Strength (N/mm^2)	Ultimate Tensile Strength (N/mm^2)	Elongation (%)
Pure	137	268	4.2
1%Al_2O_3+1%Mg	139	271	3.8
2%Al_2O_3+1%Mg	143	278	3.5
3%Al_2O_3+1%Mg	147	283	3.2
4%Al_2O_3+1%Mg	149	287	3.1

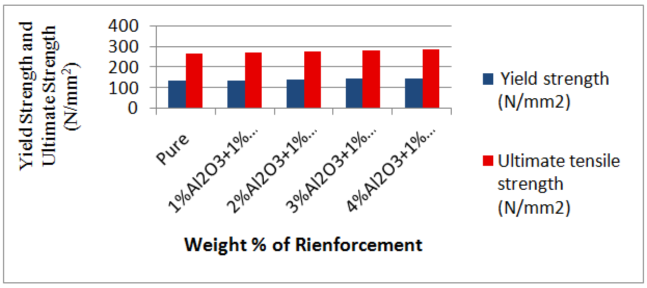


Figure 6: Tensile Test Specimen for Different Compositions

The increase in yield and ultimate strength values with different weight % of Nano Al_2O_3 are shown in Figure 6. From the chart, it is clear that tensile strength increases with increasing weight % of Nano Al_2O_3 and reducing particle dimension.

Hardness Test

Macro Hardness (ASTM E10-17)

The Brinell hardness of Al7075 base matrix and their composites containing 1-4 wt. % of Al_2O_3 are assessed using diamond indenter. From the Table 6, it can easily observe that the hardness of the composite is higher than that of its cast matrix alloy.

Table 6: Macro Hardness

Sample No	Alloy Al 7075	Hardness Brinell hardness Trail 1	Trail 2	Trail 3	Mean Hardness
1	Pure	57.3	57.5	58.9	57.9
2	$1\%Al_2O_3$+1%Mg	59.9	60.1	59.2	59.7
3	$2\%Al_2O_3$+1%Mg	60.1	60.2	62.4	60.9
4	$3\%Al_2O_3$+1%Mg	66	65.5	67.7	66.4
5	$4\%Al_2O_3$+1%Mg	70.1	74.2	76.6	73.6

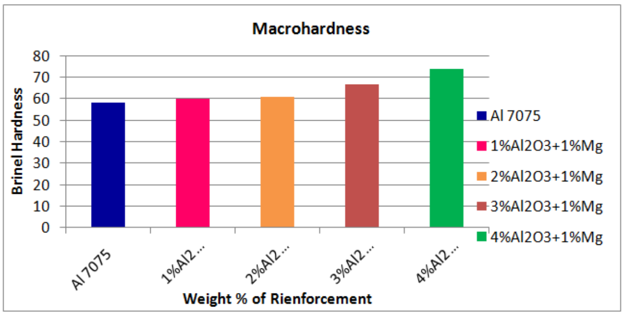


Figure 6: Macro Hardness Test Specimen for Different Compositions

Figure 6 Shows the Macro hardness values with increasing weight% of aluminum oxide content, the Macro hardness values gradually increase and the maximum value obtained at 4 Weight % of aluminum oxide particles.

Micro Hardness (ASTM E92-17)

Vickers microhardness test is done in the hardness testing equipment to find the hardness values in the Al7075/ Al_2O_3 composite sample as per ASTM E 92-17 standards. In this experiment, a diamond intended having a diameter of 10mm and load carrying capacity of 100N applied to the specimen for 10 seconds.

Table 7: Micro Hardness

Sample No	Alloy	Hardness Vickers Micro Hardness Trail 1	Trail 2	Trail 3	Mean Hardness
1	Al 7075	98	85	89	90.6
2	$1\%Al_2O_3$+1%Mg	109	113	115	112.3
3	$2\%Al_2O_3$+1%Mg	120	128	123	123.6
4	$3\%Al_2O_3$+1%Mg	110	107	113	110.0
5	$4\%Al_2O_3$+1%Mg	137	134	129	133.3

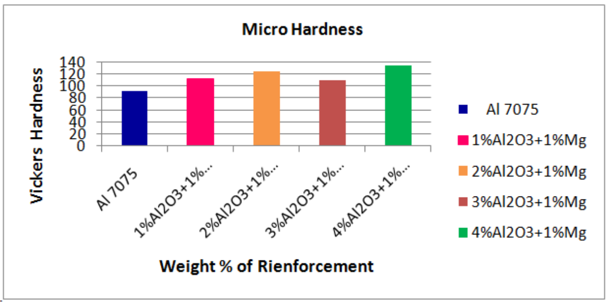


Figure 7: Micro Hardness Test Specimen for Different Compositions

From Figure 7, it could be observed that the Micro hardness of the composite is remarkable to that of its base alloy. The renovation of the hardness could be associated that the Al_2O_3 has greater hardness and also its existence in the base matrix enhances the hardness of the composite [12]. Micro hardness of the Al7075–Al_2O_3composite material rises by an amount of 47.1% as the reinforcement of Al_2O_3 increases from 0 to 4 Weight percentage.

Impact Strength

Impact strength is the capability of a material to withstand a heavy load without failure. It is also known as toughness. The Charpy test was done on the Al7075/Al_2O_3 sampling as per ASTM E23-12C [14]. The results show a gradual increase in toughness by incorporating Nano Al_2O_3 in the base alloy.

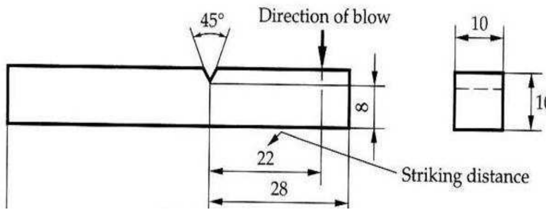


Figure 8: Impact Stress Specimen

Table 8: Impact Strength

Sample No	Alloy	Charpy Test Values			Average Force (Nm)
		Trail 1	Trail 2	Trail 3	
1	Al 7075	7.5	7.2	7.8	7.50
2	1%Al_2O_3+1%Mg	8	7.8	7.5	7.76
3	2%Al_2O_3+1%Mg	8.4	8.7	8.5	8.53
4	3%Al_2O_3+1%Mg	8.7	8.6	8.9	8.73
5	4%Al_2O_3+1%Mg	9.5	9.3	9.6	9.46

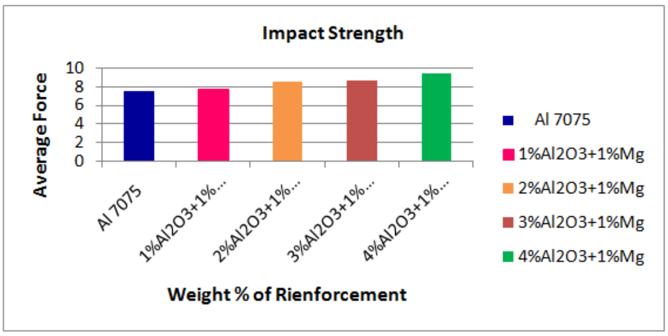


Figure 9: Impact Strength for Different Compositions

Figure 10 shows the variation of toughness of Al7075 alloy and also Al7075-Al_2O_3 composite. When contrasted with Al7075 base alloy, it is observed that there is a significant progress in the toughness of the composite when contrasted with the unreinforced alloy, an improvement of 26.1% is observed in Table 8.

ENERGY DISPERSIVE X-RAY SPECTROSCOPY

Energy dispersive X-ray spectroscopy also known as EDS analysis is a technique that can ensure details about the elemental characterization of a sample.

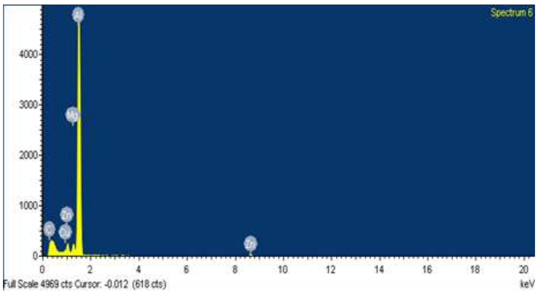


Figure 10: PURE Al 7075

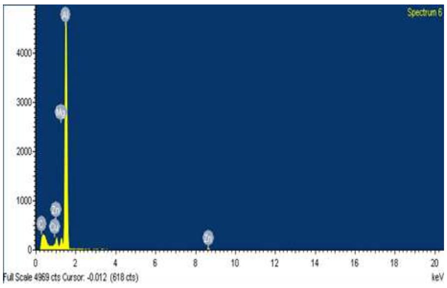


Figure 11: 1%Al_2O_3+1%Mg

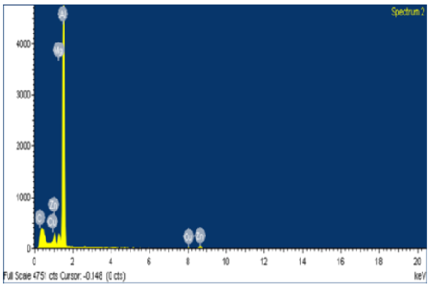


Figure 12: 2%Al_2O_3+1%Mg

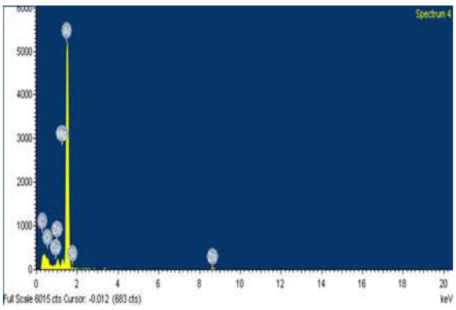


Figure 13: 3%Al2O3+1%Mg

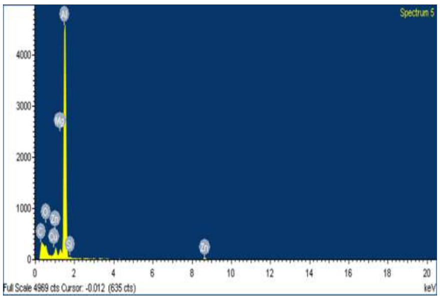


Figure 14: 4%Al2O3+1%Mg

SCANNING ELECTRON MICROSCOPY

SEM Analysis offers useful information for metallurgical examination, micro evaluation, and failure analysis. Scanning electron microscopy is carried out at very high magnifications, produces high-resolution pictures and assesses explicitly, extremely tiny characteristics and items.

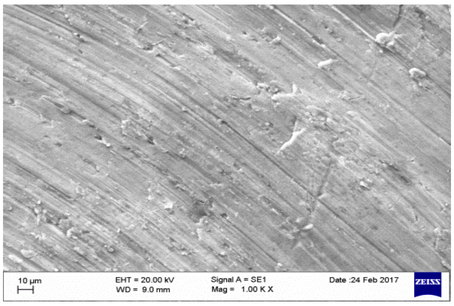


Figure 15: Pure Al 7075

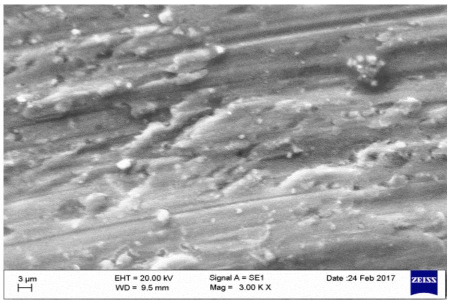


Figure 16: 1%Al2O3+1%Mg

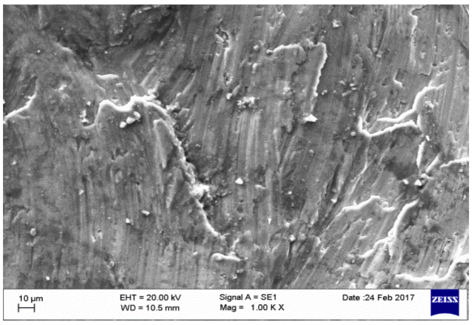


Figure 17: 2%Al2O3+1%Mg

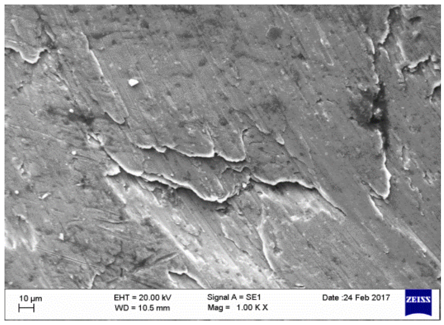


Figure 18: 3%Al2O3+1%Mg

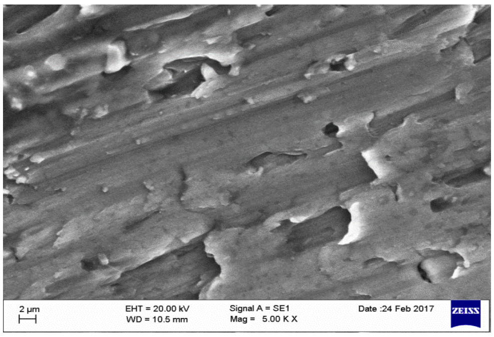


Figure 19: 4%Al2O3+1%Mg

From the above Figures 15, 16, 17, 18, 19, we identify that reinforcement| particles are fairly dispersed in the matrix. From this, we could state this compound is uniform. Since the distribution of reinforcement is homogeneous, it has raised the mechanical property of the composite.

CONCLUSIONS

In the present investigation, aluminum alloy 7075 reinforced by 1.0, 2.0, 3.0, and 4.0 Weight % of Al_2O_3 Nanoparticles fabricated by stir casting technique. From the experimental outcomes, the following conclusions were obtained.

- Aluminium matrix (1, 2, 3 and 4 Weight %) of Al_2O_3 composites have been successfully fabricated by the electric stir casting process.
- The experimental density is nearer to the theoretical density of composites. The porosity of composites could be decreased significantly due to the addition of 1% of magnesium.

- The Tensile strength, hardness, and toughness increases by increasing Weight % of Al_2O_3 when compared to the base metal.
- Optical micrographs, EDX and SEM photographs exposed that the Al_2O_3 particles were well dispersed in the Aluminium matrix.

SCOPE OF FUTURE WORK

- The research work further extended by changing geometrical angle of Stirrer, stirring time and stirring speed.
- The heat treatment can be done to improve the Mechanical and Tribological properties.
- Varying reinforcement Grain Size can vary results.

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